Darwin builds better cars

Lessons evolving online vehicles

NABT 2012

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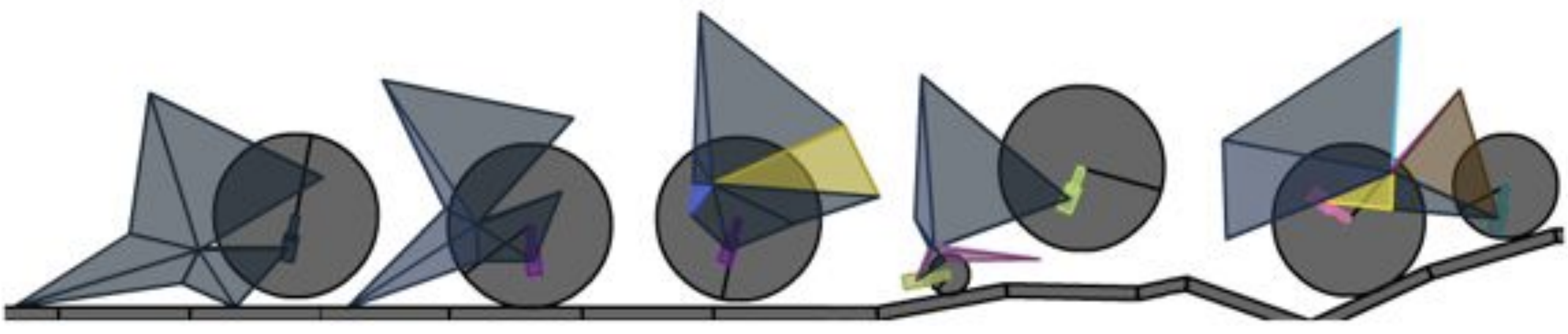


Evolution & Engineering

- Introduce a program that incorporates evolutionary and engineering principles to build cars best adapted to their track
- Designing vehicles is a great hook to get students thinking about adaptation and evolution

You as an engineer:

Create a car that is best adapted to it’s environment

(a car’s “fitness” is dependent on how far it can travel in the environment)

Evolution & Engineering

- Introduce a program that incorporates evolutionary and engineering principles to build cars best adapted to their track
- Designing vehicles is a great hook to get students thinking about adaptation and evolution
- Start with Lego cars to get them engaged
- Move into working with online program
    - Testing convergent evolution and adaptation
- Extend the lesson to combine natural selection with design

You as an engineer:

build the best Lego car you can

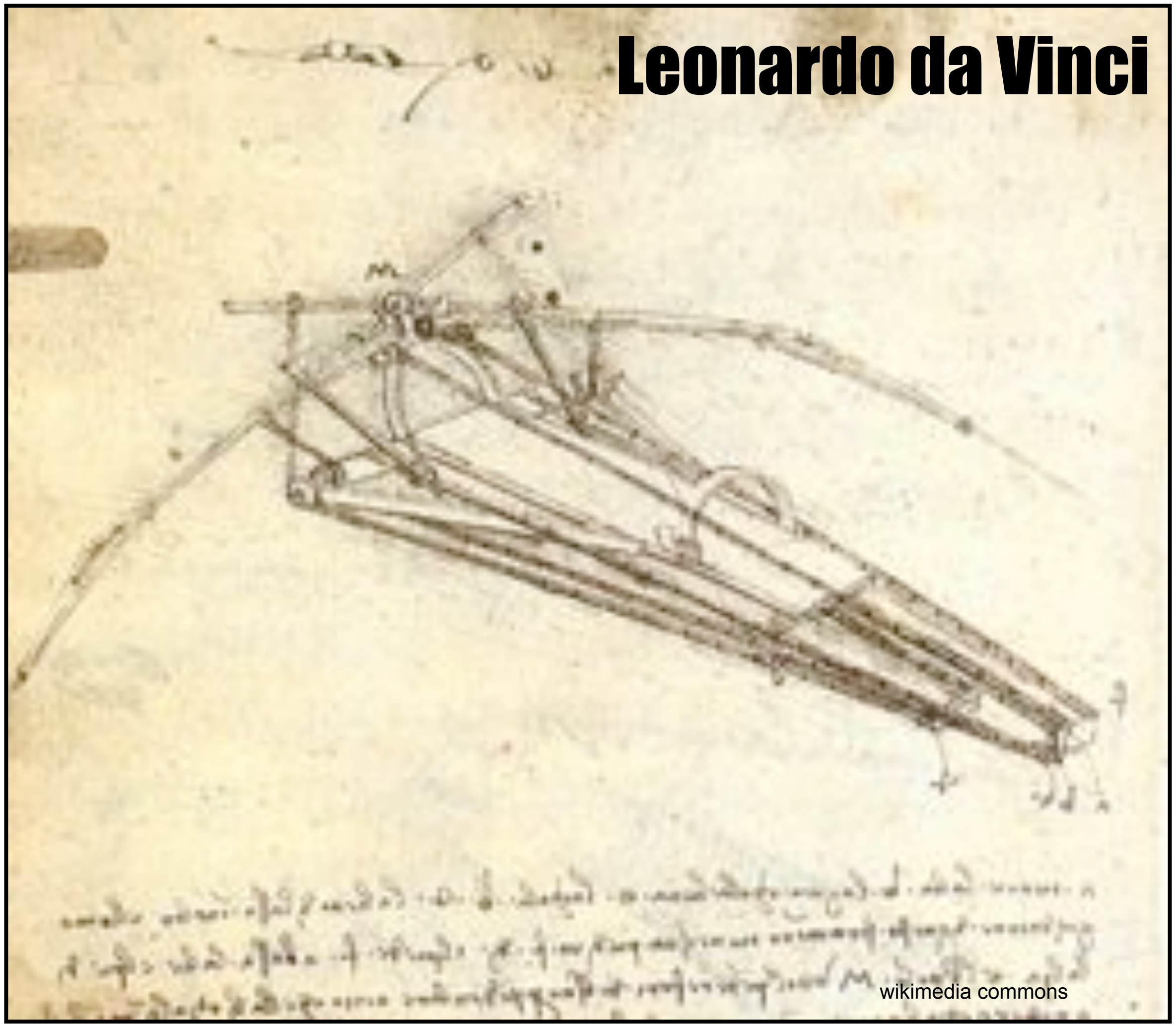
YOU CAN USE:

- Up to four wheels (0-4)
- One platform (gray piece)
- Up to four additional parts (0-4) (any other color)

Trial runs: the goal is to get your car to go as far as possible – write name and best time on the board

After everyone has their starter pieces, you can pick up more pieces (or remove them!) to engineer a faster car

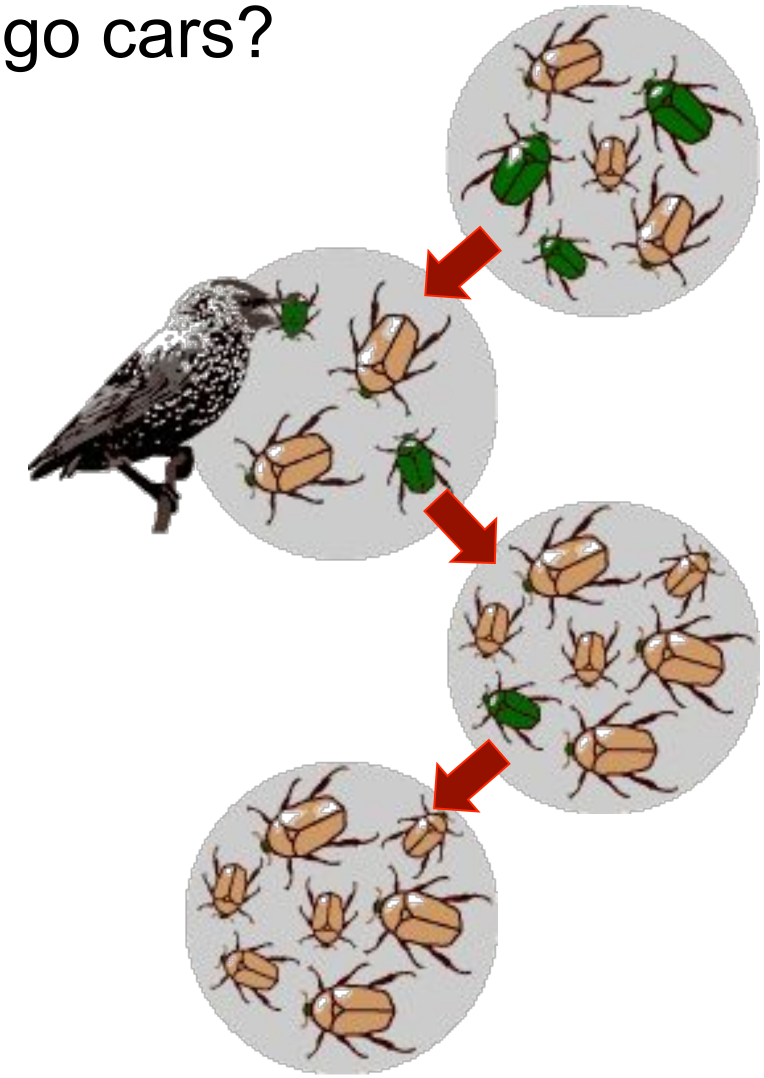
Integrating evolution and engineering:
Using biological concepts to solve problems



Evolution as a process:

How can we use principles from evolution
to improve our Lego cars?

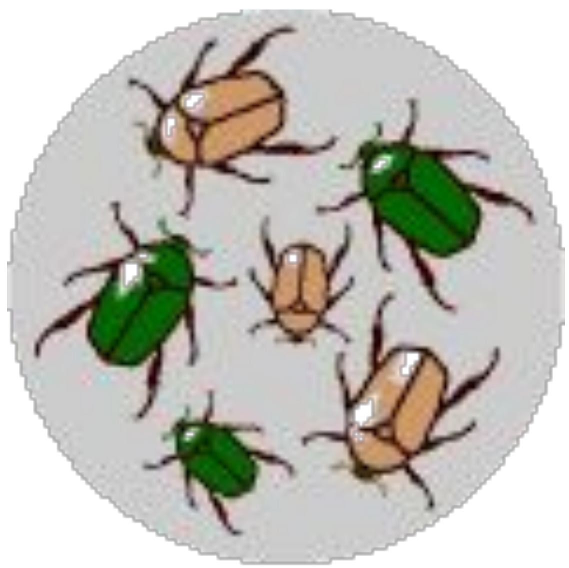
- **V**ariation
- **I**nheritance
- **S**election
- **T**ime



Evolution as a process:

How can we use principles from evolution to improve our Lego cars?

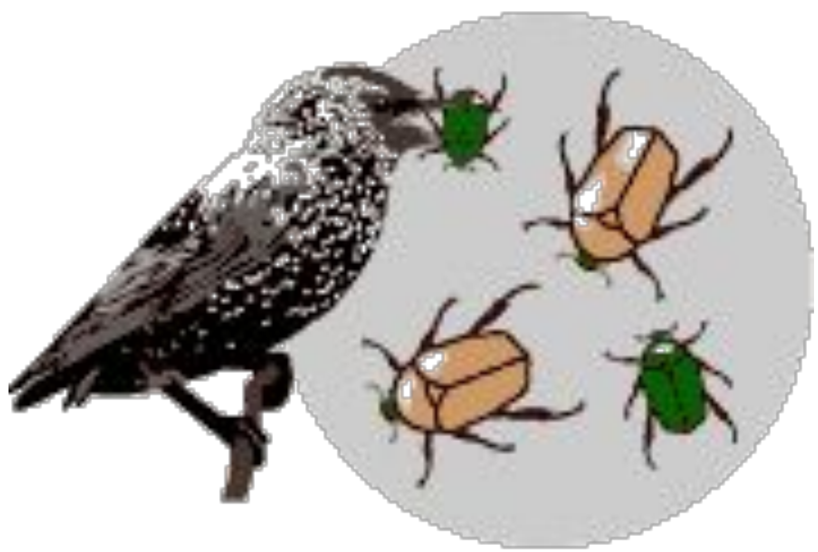
- Variation: the fuel for natural selection



Evolution as a process:

How can we use principles from evolution to improve our Lego cars?

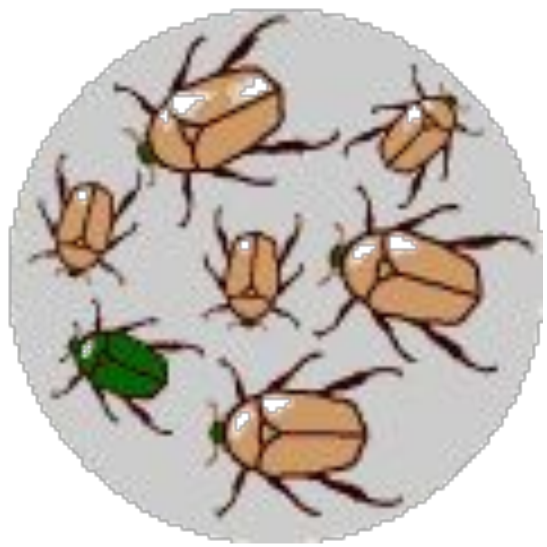
- Selection: acts on variation in a non-random way, leaving behind individuals with beneficial traits



Evolution as a process:

How can we use principles from evolution to improve our Lego cars?

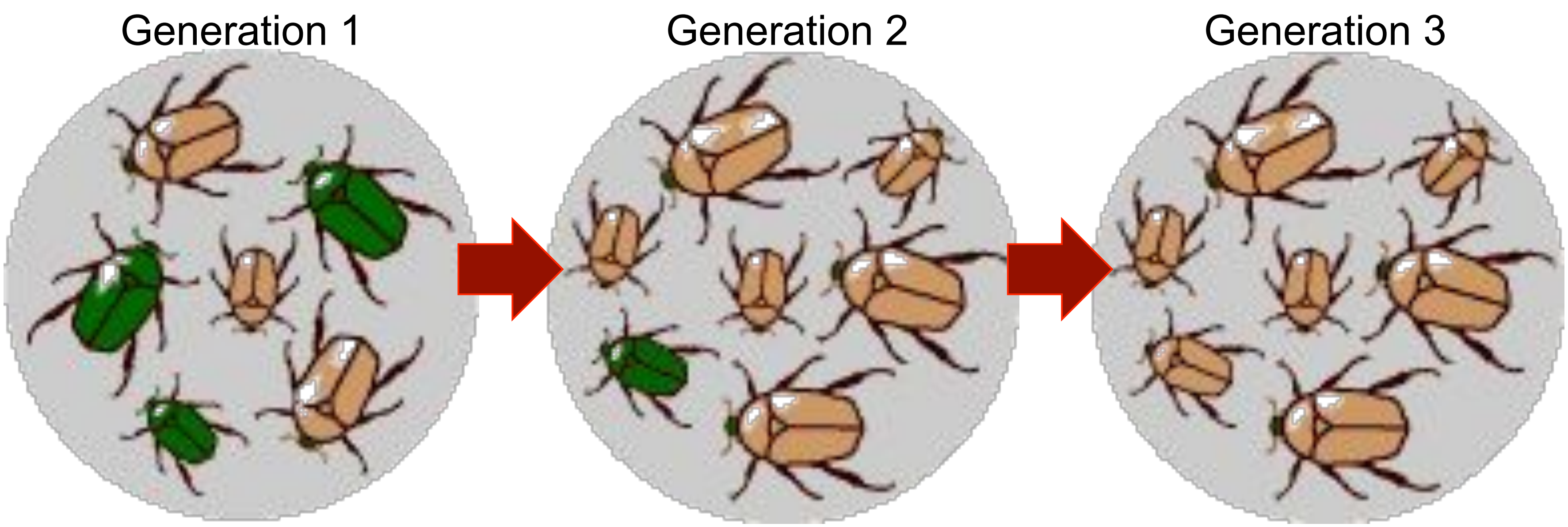
- Inheritance: individuals with beneficial traits will survive better and pass on more genes to future generations



Evolution as a process:

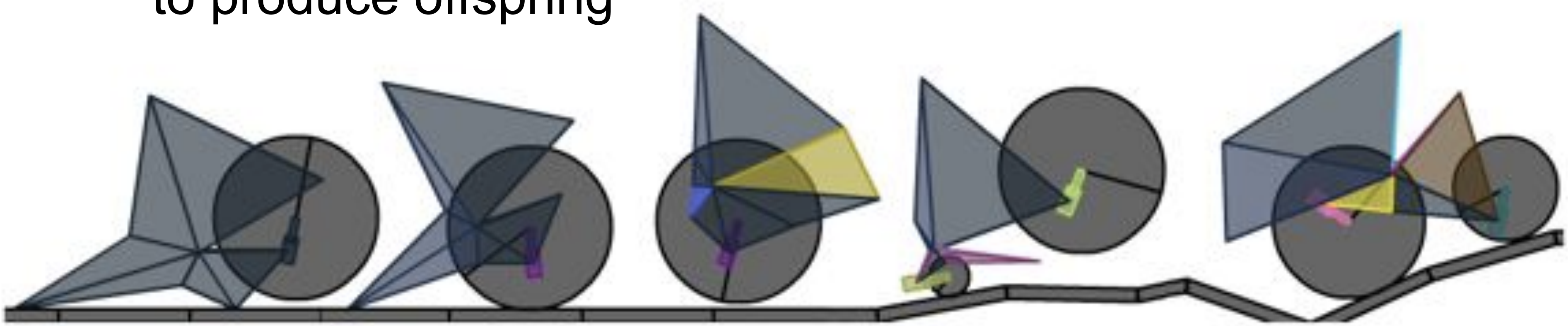
How can we use principles from evolution to improve our Lego cars?

- Time: over many generations, the beneficial adaptations will spread through the population



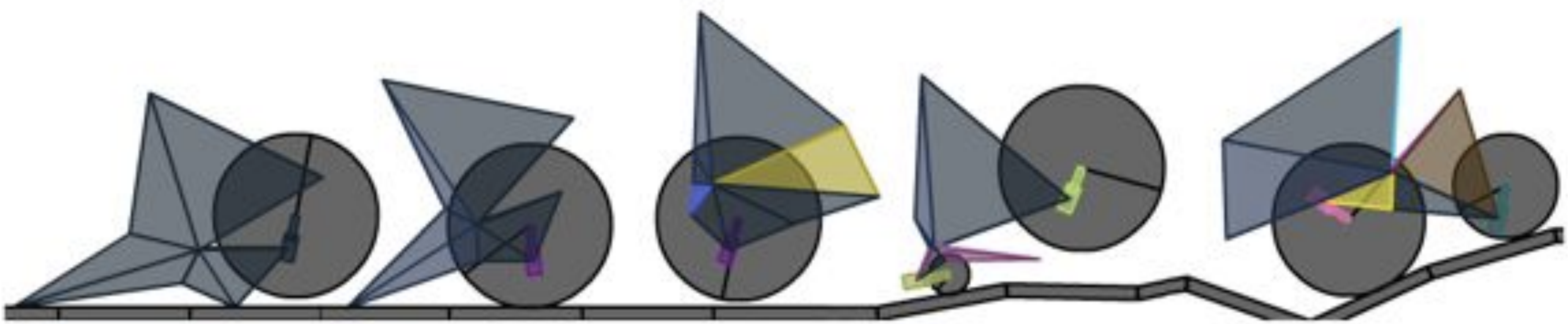
Evolution and Engineering: BoxCar2D

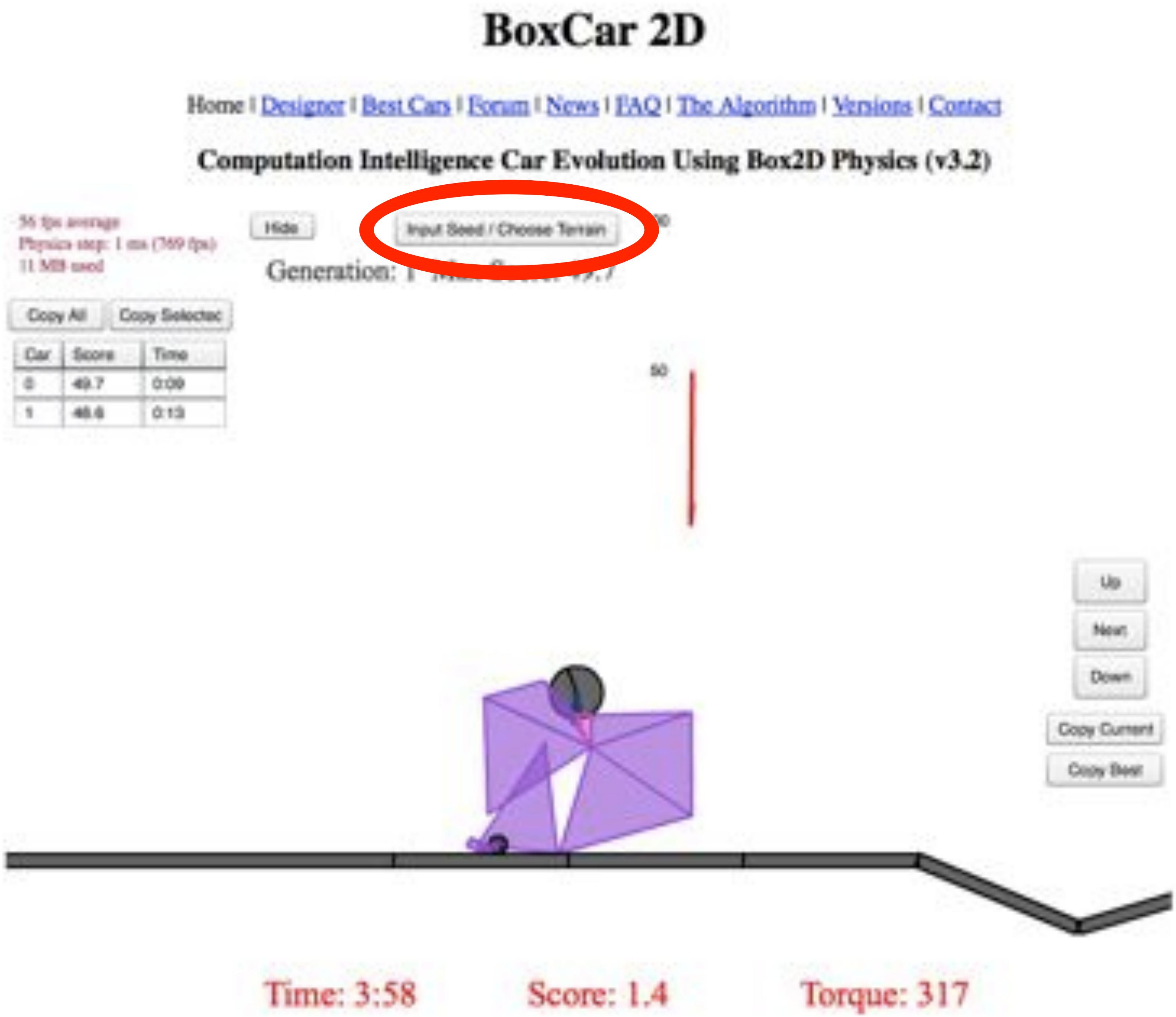
- Computer program for vehicle evolution developed by Ryan Weber
- Virtual environment including the effects of gravity, friction, collisions, motor torque, and spring tension
- Each car represents an individual in a population
- Each generation the cars move along a track, with distance traveled considered their "fitness"
- To produce the next generation, cars mate - their traits recombine, and some mutation adds additional variation to produce offspring



Open web browser and go to:

www.BoxCar2D.com




BoxCar 2D
Home | Designer | Best Cars | Forum | News | FAQ | The Algorithm | Versions | Contact
Computation Intelligence Car Evolution Using Box2D Physics (v3.2)
Hide
Input Seed / Choose Terrain
Generation: 1
Copy All
Copy Selected
Car
Score
Time
0
49.7
0:09
1
46.6
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50
Up
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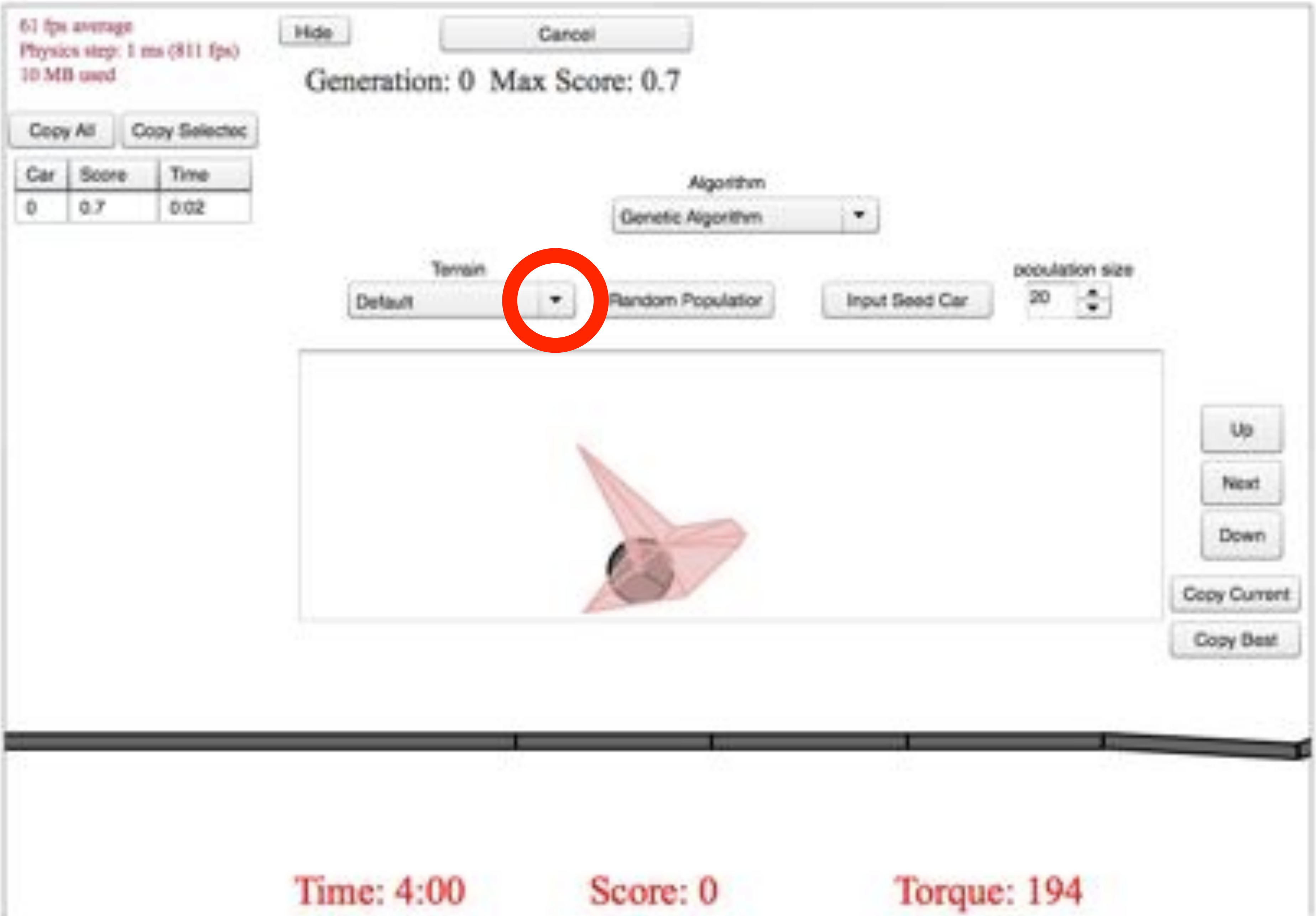
Time: 3:58
Score: 1.4
Torque: 317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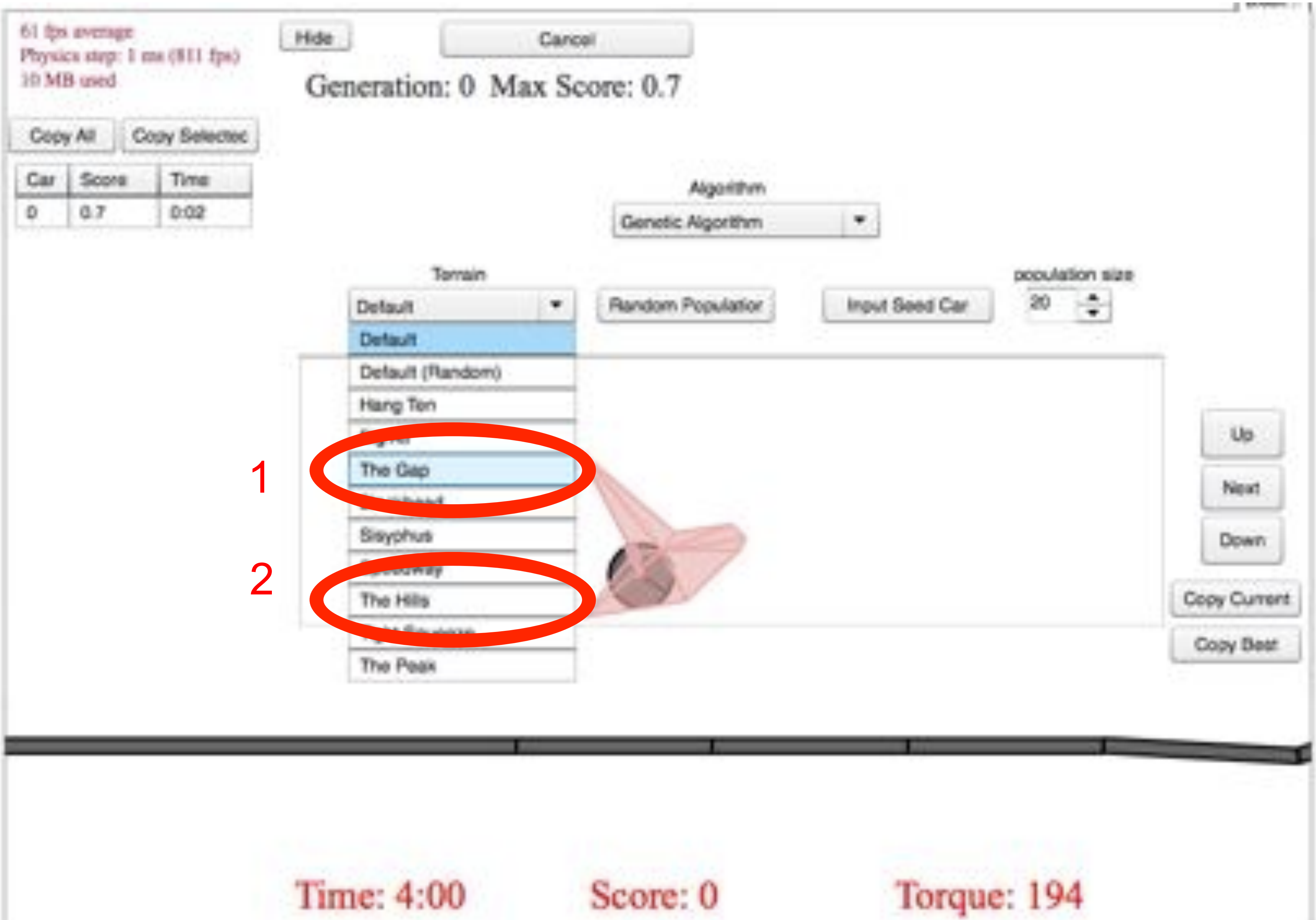
Torque: 194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Algorithm
Genetic Algorithm
Terrain
Default
Random Populatior
Input Seed Car
population size
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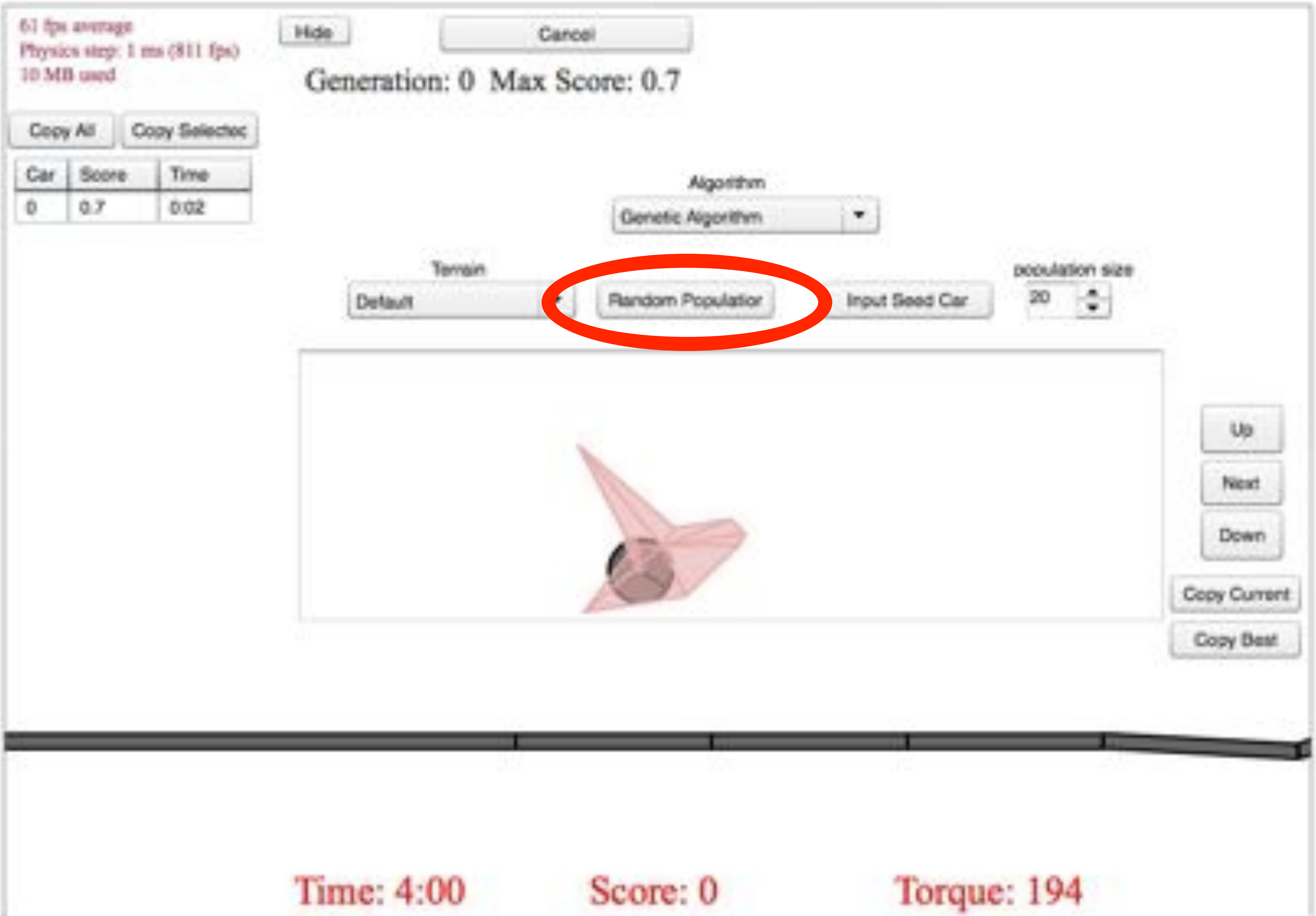
Score: 0
Torque: 194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Terrain
Default
Random Population
Input Seed Car
population size
20
Up
Next
Down
Copy Current
Copy Best
Time: 4:00
Score: 0
Torque: 194

BoxCar2D Worksheet: beginning

Name ________________ Date________

Track___________

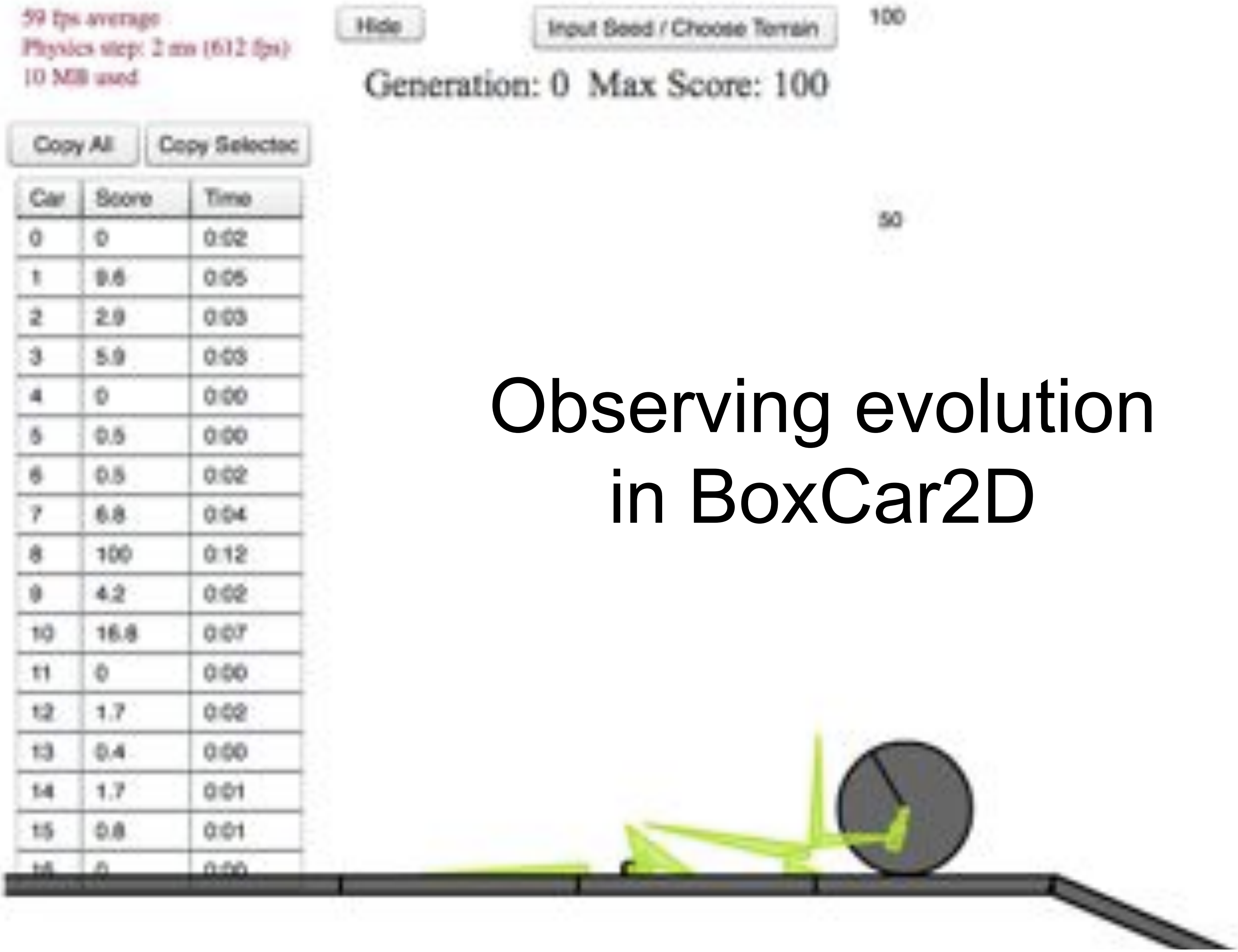
Observing evolution by natural selection in BoxCar2D
(note interesting things you see – don't have to record everything!)

Generation	Car #	Score	Time	Notes

Keep this round of evolution running in the background

Don't close the window or open new tabs – only open new windows!!

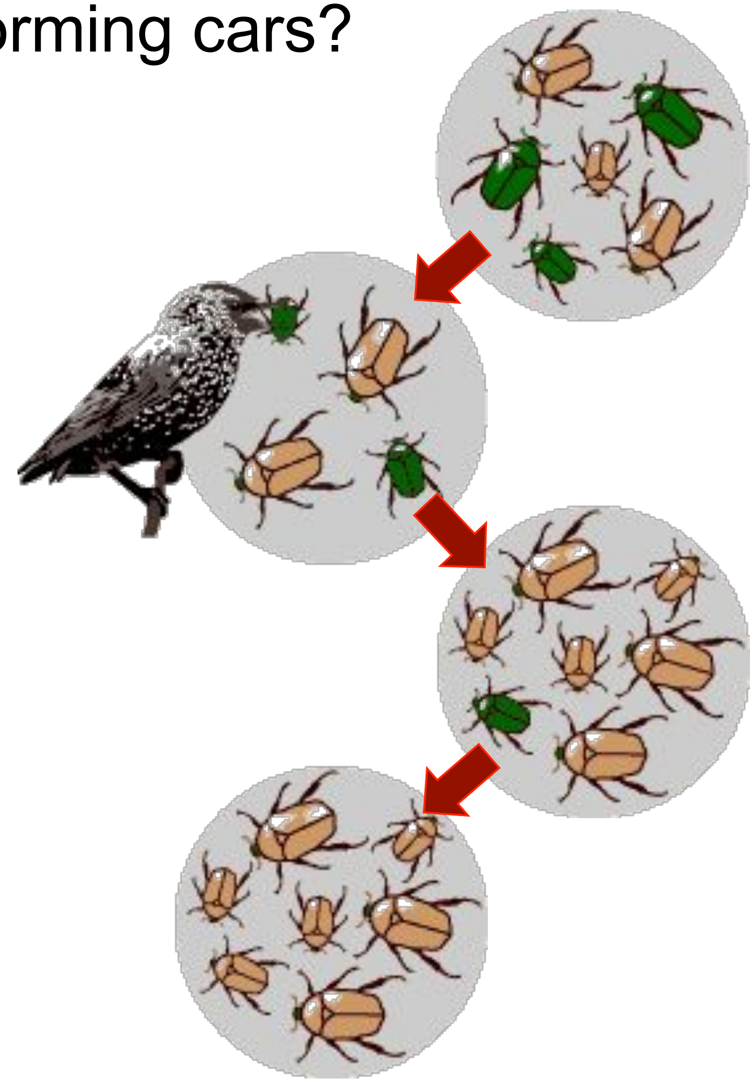
Observing evolution in BoxCar2D



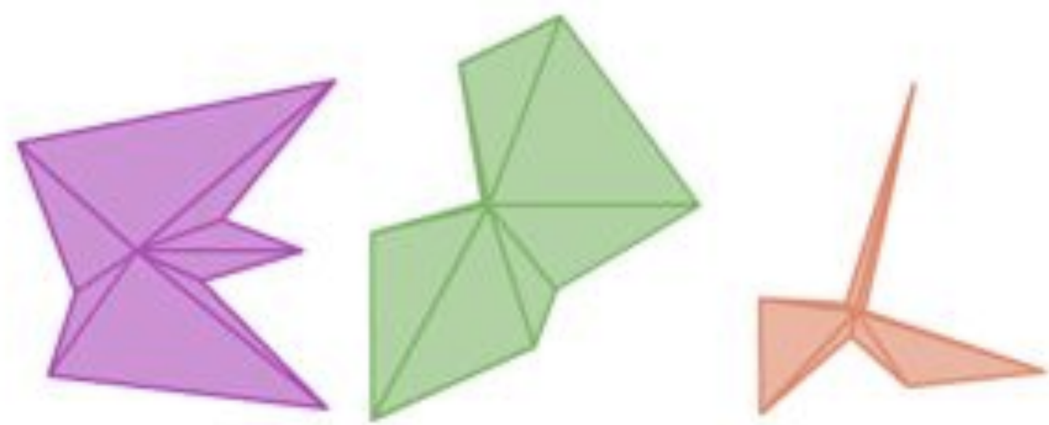
Evolution & Engineering:

How does BoxCar2D use principles from evolution to develop better performing cars?

- Variation
- Inheritance
- Selection
- Time



Evolution as a process:
variation



Each car is represented by one chromosome, with 40 variables on each chromosome

All of the car's traits are coded on the chromosome: how many wheels, angles, length, speed…

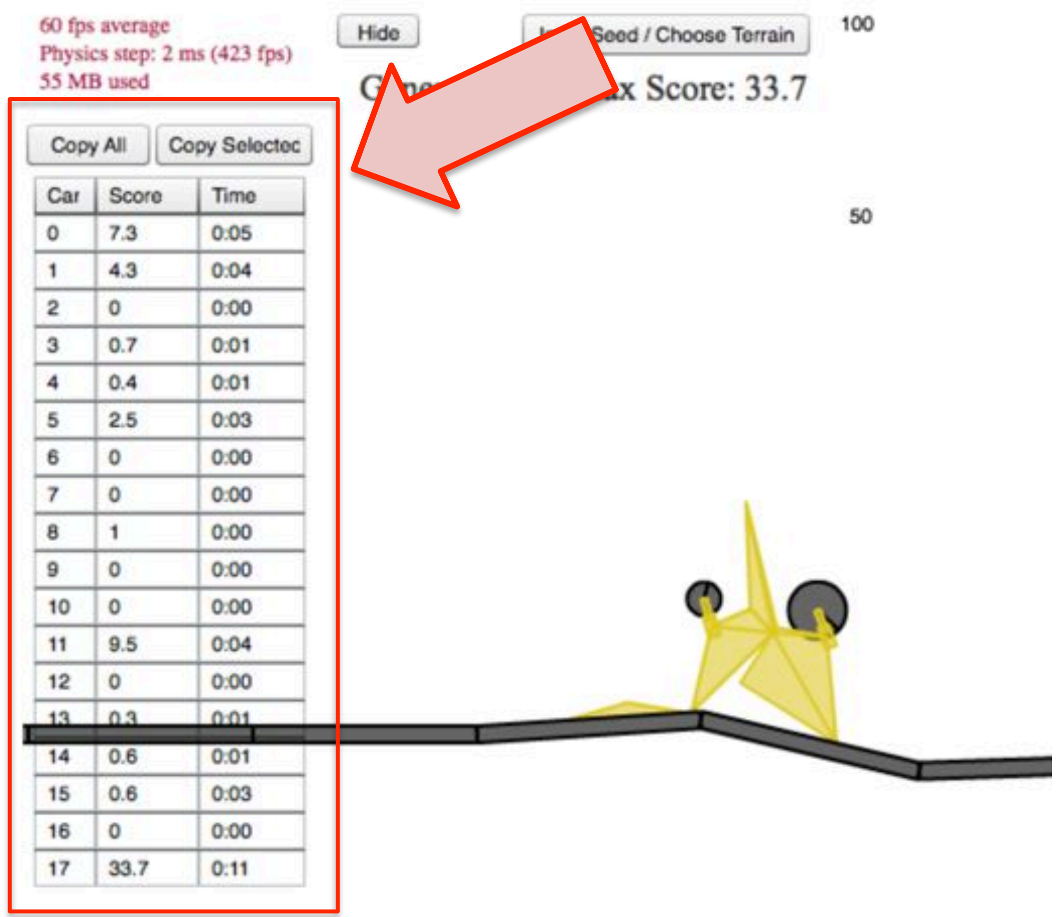
Evolution as a process:
variation

- Where does the variation come from?
- Initial variation from randomly-generated cars
- Chromosomes undergo mutation at a user-set rate each generation; mutated traits are marked by a color change

---	---	Angle5	Mag5	---	---	---	---	WheelVertex0
0.305	2.752	0.376	2.507	0.814	1.963	0.392	2.872	3
0.305	2.752	0.376	[illegible]	0.814	1.963	0.392	2.872	4

Evolution as a process:
variation

Each population contains 20 unique individuals

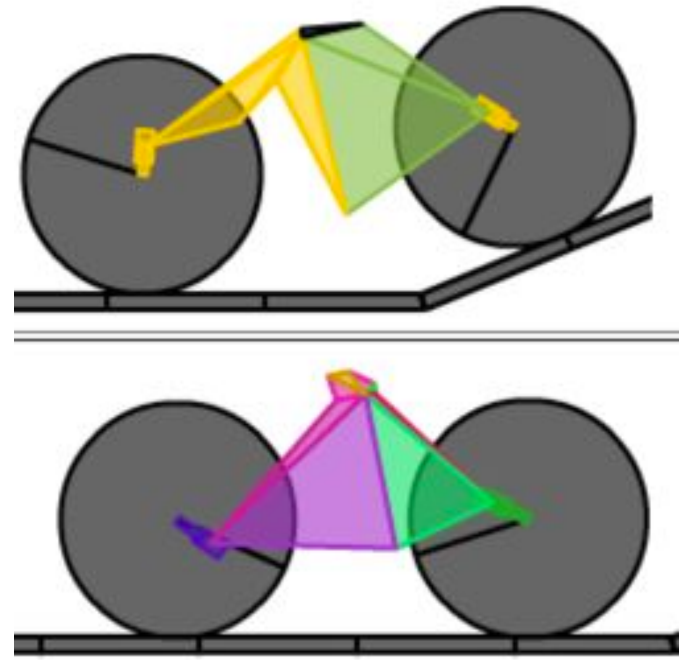


Car	Score	Time
0	7.3	0:05
1	4.3	0:04
2	0	0:00
3	0.7	0:01
4	0.4	0:01
5	2.5	0:03
6	0	0:00
7	0	0:00
8	1	0:00
9	0	0:00
10	0	0:00
11	9.5	0:04
12	0	0:00
13	0.3	0:01
14	0.6	0:01
15	0.6	0:03
16	0	0:00
17	33.7	0:11

Evolution as a process:
selection

At the end of each generation, cars are paired up to “reproduce”

Cars that move the furthest get “mated” most often, so they contribute most to the next generation

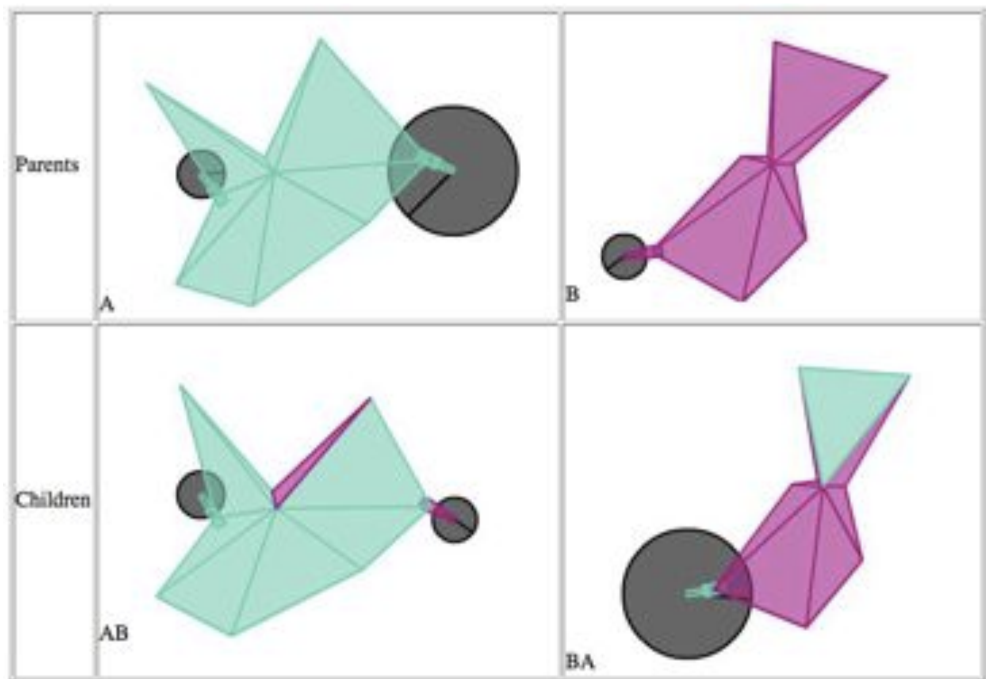


Evolution as a process:
inheritance

Car	Angle0	Mag0	Angle1	Mag1	...	...	...	...	...	...	...	AxleAngle1	WheelRadius1
A	0.769	2.614	0.584	0.319	0.278	2.883	0.666	1.13	0.305	2.752	0.376	2.625	1.191
B	0.535	2.682	0.732	2.256	0.422	0.149	0.676	0.578	0.709	2.774	0.592	0.167	0.409
AB	0.535	2.682	0.584	0.319	0.278	2.883	0.666	1.13	0.305	2.752	0.376	2.625	0.409
BA	0.769	2.614	0.732	2.256	0.422	0.149	0.676	0.578	0.709	2.774	0.592	0.167	1.191

A lot like meiosis…

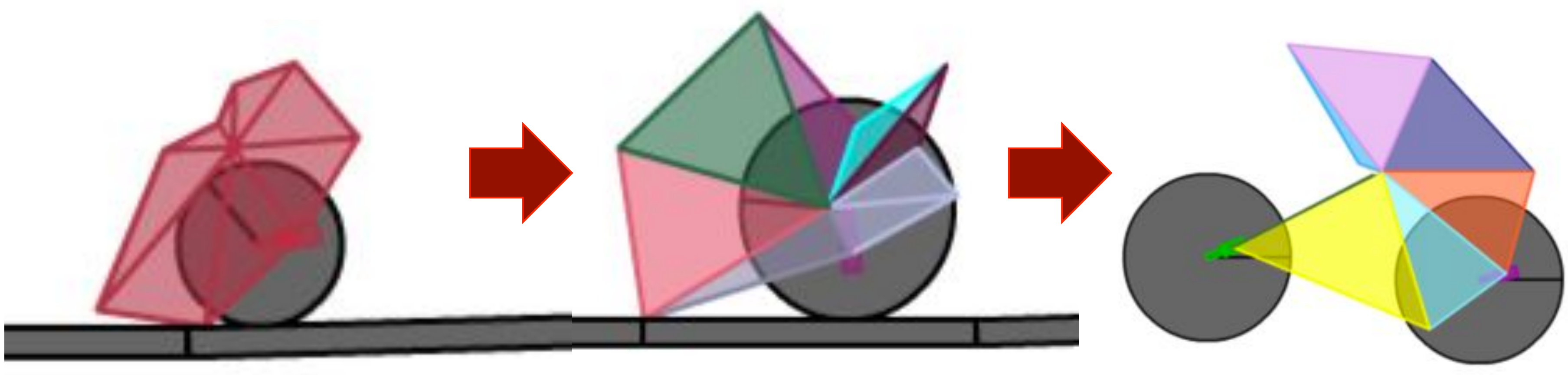
Parent chromosomes "cross over" twice to produce offspring that are a mixture of traits



Evolution as a process:
time

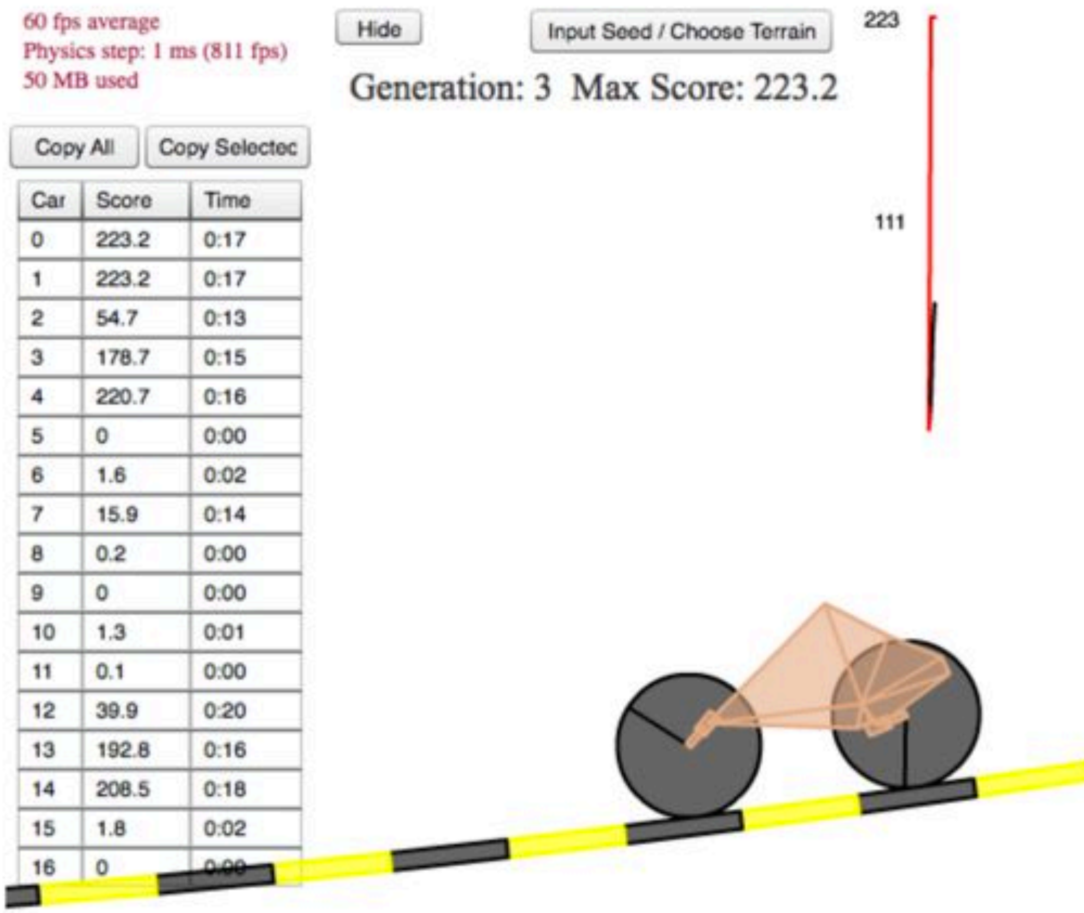
over many generations, adaptations will spread through the population; traits that work less well will dwindle

Generation 1 Generation 30 Generation 90



Evolution as a process: time

- Keep the program running for many generations, and watch the cars evolve over time!

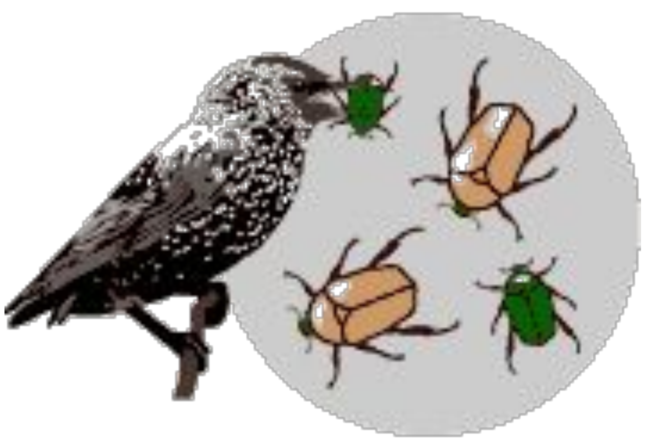


Evolution as a process:

- Variation
- Inheritance
- Selection
- Time (generations)
- Design??

BoxCar allows you to add design into your vehicles along the way

- How does this differ from evolution by natural selection?
- What are potential issues to address when using BoxCar to reinforce principles of evolution in your classroom?



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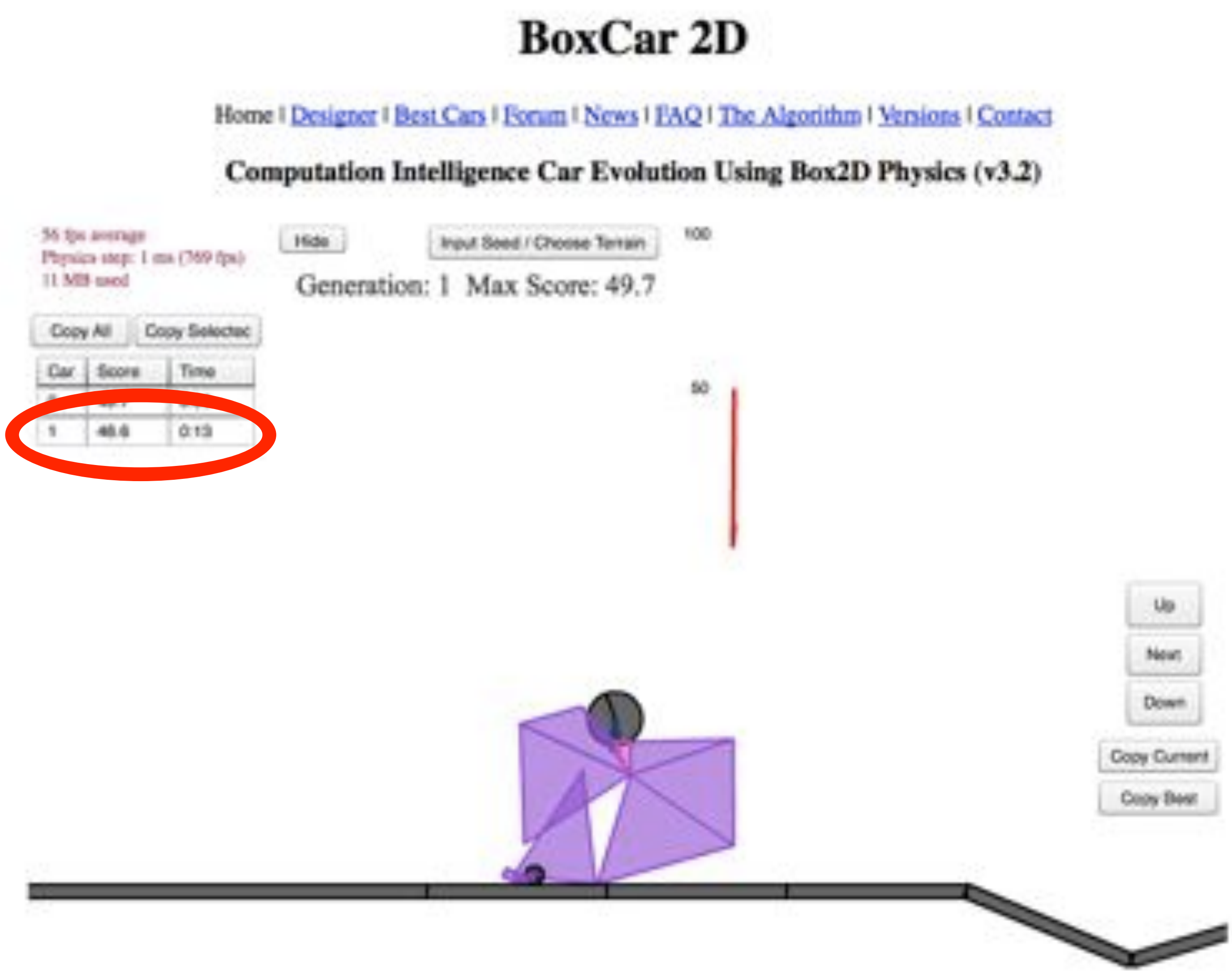
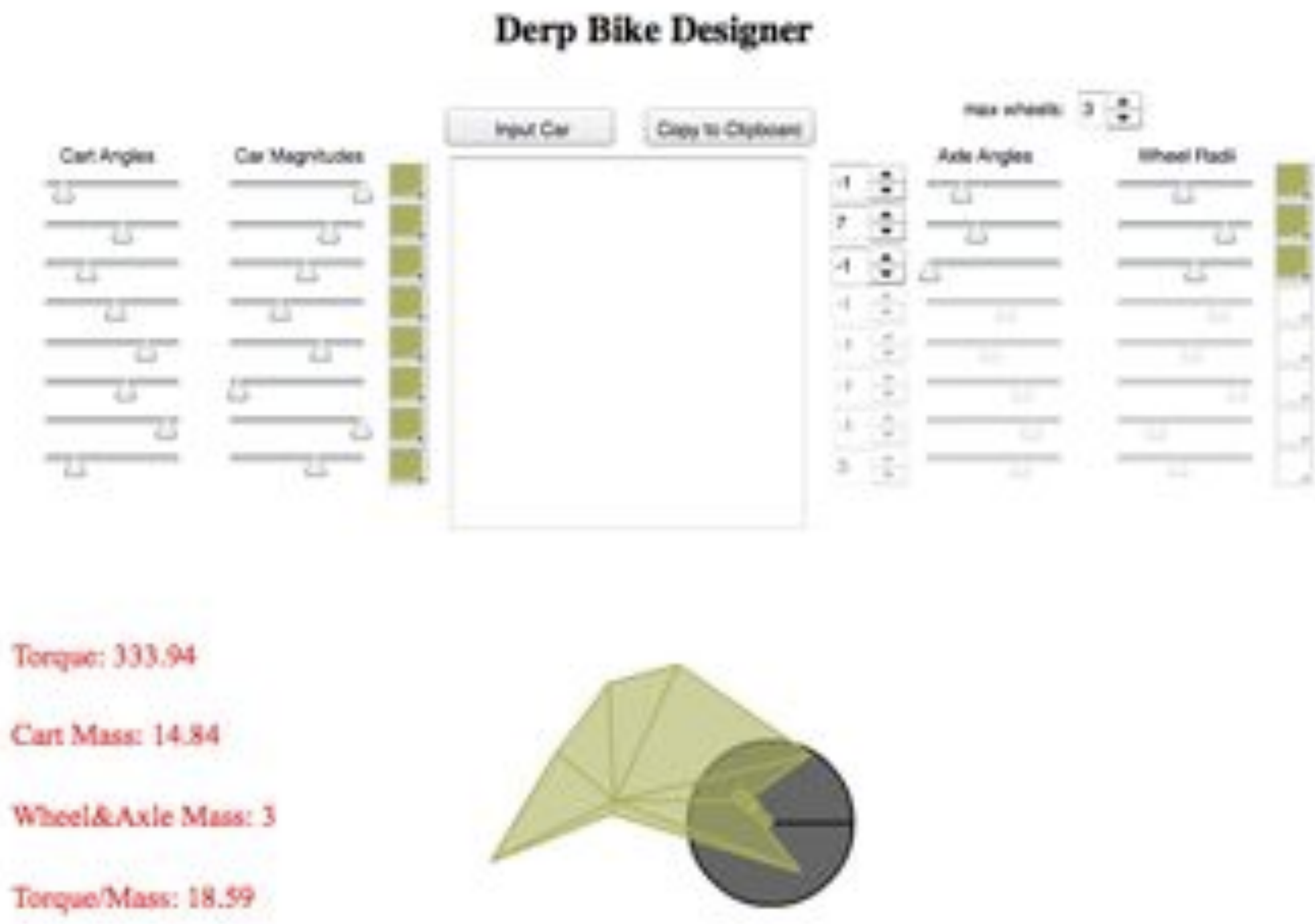


COPYING A CAR OUT OF THE POPULATION:
-Click on the row in the table representing the car you want
-Click "copy selected"
-Paste into a new population on a new track, or back into the designer

Evolution with hand-engineering in BoxCar2D

(excerpted from boxcar2d.com/about.html)



Evolution with hand-engineering in BoxCar2D

(excerpted from boxcar2d.com/about.html)

INSTRUCTIONS WILL STAY ON THE SCREEN- DON'T COPY THEM DOWN!

- Importing your designed car into the program:
  - In the Derp Bike Designer, click "copy to clipboard"
  - Go to the main page, click "input seed/choose terrain" – keep on the same track
  - Click in the box that pops up and hit control-V to paste your car's code
  - Click "input seed car" to start running
- Your car will show up first; the next ones in the population will be mixtures of your design and random cars

BoxCar2D Design Worksheet: beginning

Name ___________________ Date_________

Track_____________

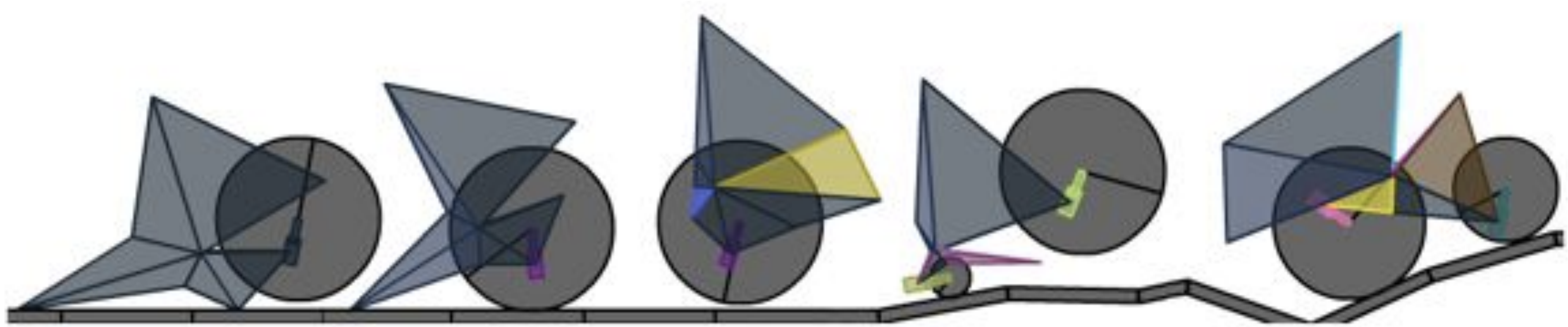
Draw your design

Score and time of hand-designed car:

Observe the population - record interesting points (not everything!)

Generation	Car #	Score	Time	Notes

- Share some of the cars that are evolving
- Do different populations on the same track look similar? Would we expect them to?
- What traits (features of your successful cars) do you think might be adaptations to your track?



Convergence

- Independent evolution of a similar solution to the same kind of natural selection (looks the same, but took a different path to get there)
- Engineering: different ways to solve the same problem
- Brainstorm – examples? (Engineering or biology)


GOODYEAR
TAROM
LAPD
avantiHP

Extensions

- Testing predictions about manipulating population size and/or mutation rate
- Tree thinking: building evolutionary trees, saving code or images of cars at nodes as “fossils”
- Invasiveness: in reciprocal transplants, do cars evolved on track “A” ever do better on track “B” than cars evolved on track “B”?
- Full-circle inquiry exercises
  - Students come up with their own questions
  - Emphasizing replication
  - Statistical testing – t-test or ANOVA using fitness

Cool cars!

- eNqzfxySMo1Vbqf9z
+ZNZoJaFvYrZ4LALAe2A6tOmD2ot3+mphD6/7a1/
Rt5N+dpTU/s72gu3Xo/Pt/+n6zx9Q0xn
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QUESTIONS, FEEDBACK?